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General Certificate of Education (A-level)
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Mathematics MD02

(Specification 6360)

Decision 2

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Key to mark scheme abbreviations

M	mark is for method
m or dM	mark is dependent on one or more M marks and is for method
A	mark is dependent on M or m marks and is for accuracy
B	mark is independent of M or m marks and is for method and accuracy
E	mark is for explanation
√or ft or F	follow through from previous incorrect result
CAO	correct answer only
CSO	correct solution only
AWFW	anything which falls within
AWRT	anything which rounds to
ACF	any correct form
AG	answer given
SC	special case
OE	or equivalent
A2,1	2 or 1 (or 0) accuracy marks
–*x* EE	deduct *x* marks for each error
NMS	no method shown
PI	possibly implied
SCA	substantially correct approach
c	candidate
sf	significant figure(s)
dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

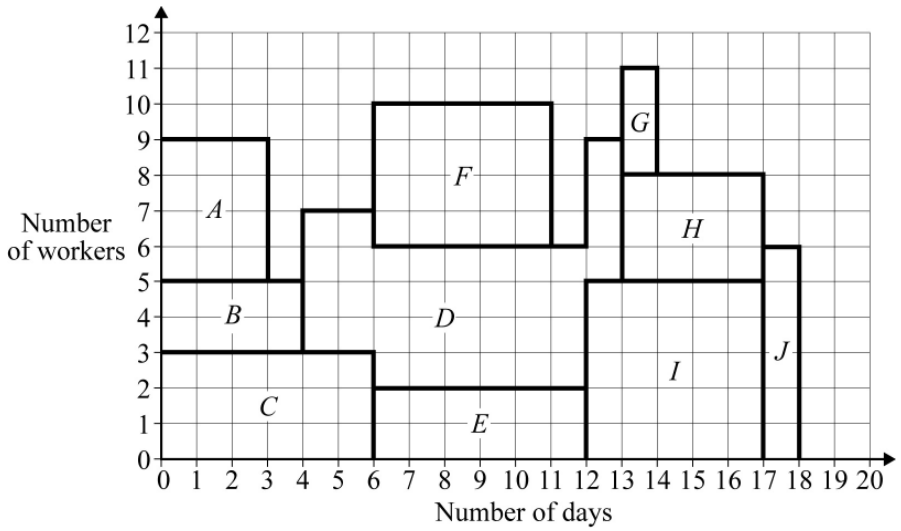
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

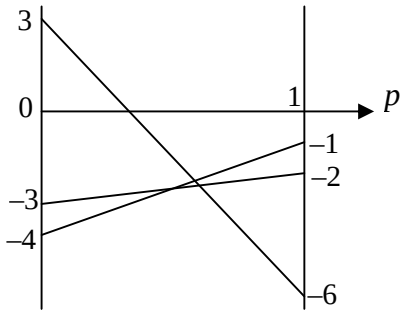
MD02

Q	Solution	Marks	Total	Comments
1(a)	$x = 4$ $y = 12$ $z = 13$	B1 B1 B1	3	
(b)	*B D H J* and *C E I J*	M1 A1	2	first correct path 2nd correct and no others
(c)	*G* Float = 3	B1 B1	2	
(d)	One of their CPs correct height *B, D, H, J* and *C, E, I* correct	M1 A1		and correct durations and correct durations
				
	A starting at 0 and ending at 3 *F* starting at 6 and ending at 11 *G* starting at 13 and ending at 14	M1 A1 A1	5	one correct with correct height two correct with correct height all correct with correct height withhold first A1 earned if it is not clear which activities take place at any given time withhold another A1 if "holes" appear in histogram
(e)	New earliest *J* 22 days	B1		assuming activities continuous
	Minimum extra time 5 days	B1	2	assuming activities continuous
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	Hungarian algorithm used to find **minimum total** **Each new entry** gives measure of points **not** scored $\Rightarrow$ Hungarian algorithm now finds maximum total score	E1 E1	2	First E1– fairly generous for idea of "minimising" or "points not scored". Second E1 is strict.
(b)	Replacing x by $35 - x$			
	8 6 10 0 4 2 13 18 6 6 12 6 10 2 14 13 6 6 8 4 8 8 16 14 8	B1		Must see this table
	8 6 10 0 4 0 11 16 4 4 10 4 8 0 12 9 2 2 4 0 0 0 8 6 0	M1		reducing rows; ft one slip from above & allow one further slip
	8 6 8 0 4 0 11 14 4 4 10 4 6 0 12 9 2 0 4 0 0 0 6 6 0	A1cso	3	check working is correct since most values in final table are given. ($p = 14$ $q = 9$)
(c)	Lines covering R_4 , R_5 and C_1 , C_4	B1		4 correct lines
	8 2 4 0 0 0 7 10 4 0 10 0 2 0 8 13 2 0 8 0 4 0 6 10 0	M1 A1	3	subtracting 4 from each uncovered and adding 4 to each double covered (condone 2 slips) all correct
(d)(i)	B1 and D3 A4 B1 C2 D3 E5 A5 B1 C4 D3 E2	M1 A1 A1	3	or one **full** matching with rings etc one correct matching second correct and no others
(ii)	Total = 153	B1	1	
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	**For each pair of strategies** Roz gain + Colum gain = 0	E2,1	2	E1 for general idea of Roz gain + Colum gain = 0
(b)	Colum's max are $-2, 3, -1$			must see these values for E1
	min (colum max) = –2	E1		
	$\Rightarrow$ play safe is C_1	B1	2	
(c)(i)	Delete R_2 (PI by further work)	M1		C_1 C_2 C_3 -2 -6 -1 R_1
	Since R_3 dominates R_2	A1	2	-3 3 -4 R_3
(ii)	Let Roz play R_1 with prob p			
	C_1 expected gain: $-2p-3(1-p)=p-3$			
	$C_2: -6p+3(1-p)=3-9p$	M1		2 expressions unsimplified ft their matrix
	$C_3: -p-4(1-p)=3p-4$	A1		all correct
		M1		plotting 3 expected gains for $0 \leqslant p \leqslant 1$
		A1		correct gains plotted accurately
	Solving $p-3=3-9p$	m1		choosing highest point of 'their' region or correct pair solved
	$\Rightarrow 10p=6$			
	$p=\frac{3}{5}$	A1		
	$\Rightarrow$ Roz plays R_1 with probability $\frac{3}{5}$ and R_3 with probability $\frac{2}{5}$	E1cao	7	must see R_1 and R_3
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	x-column pivot = 6 $\frac{2}{2}=1$, $\frac{3}{6}=\frac{1}{2}$ $\left(\text{and } \frac{1}{2}<1\right)$ smallest **positive** quotient	B1 B1 E1	3	need to see correct quotients considered negative value **must** be mentioned as being considered but rejected
(ii)	***P*** ***x*** ***y*** ***z*** ***s*** ***t*** ***u*** **value** 1 0 1 0 1 $\frac{1}{3}$ 0 7 0 0 13 1 3 $-\frac{1}{3}$ 0 1 0 1 –5 0 –1 $\frac{1}{6}$ 0 $\frac{1}{2}$ 0 0 –14 0 –4 $\frac{1}{6}$ 1 $4\frac{1}{2}$	M1 A1 A1 A1	4	row operations 1st, 2nd or 4th row correct another of these 3 correct all correct (condone multiples of rows)
(b)(i)	No negatives in **top row**	E1	1	**but** must have no negative values in "their" top row
(ii)	One (inequality still has slack)	B1	1	
(c)(i)	$P = 7$ $x=\frac{1}{2}$, $y=0$, $z=1$	B1√ B1 cao	2	FT their tableau condone one slip in final tableau
(ii)	Substituting "their" values from (c) (i) $\frac{1}{2}k + 0 + 3 = 7$ $\Rightarrow k = 8$	 M1 A1	2	
			13	

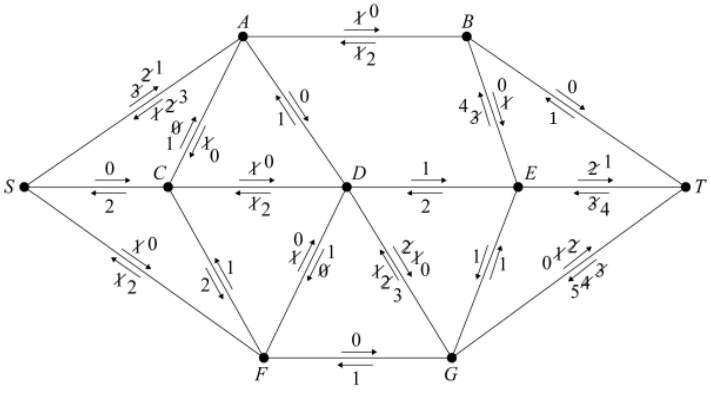
MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)				

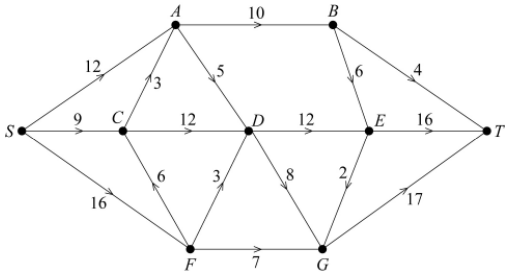
Stage	State	From	Calculation	
1	G	T		15
	H	T		17
	I	T		26
2	D	G	6 + 15	21 ←
		H	3 + 17	20
	E	G	–3 + 15	12
		H	–6 + 17	11
		I	–13 + 26	13 ←
	F	H	–7 + 17	10
		I	–14 + 26	12 ←
3	A	D	–4 + 21	17
		E	6 + 13	19 ←
	B	D	12 + 21	33 ←
		E	16 + 13	29
		F	18 + 12	30
	C	E	14 + 13	27 ←
		F	13 + 12	25
4	S	A	12 + 19	31*
		B	–2 + 33	31*
		C	3 + 27	30

Q	Solution	Marks	Total	Comments
		B1		stage 1 correct
		M1		7 values at stage 2 attempted with 5 unsimplified calculations correct
		A1		stage 2 correct
		M1		use of two of "their" maxima from Stage 2 to Stage 3
		A1		stage 3 correct
		A1cso	6	stage 4 & all other values correct
(b)	Maximum profit = 31	B1√		£31 million
	$SAEIT$ and $SBDGT$	B1 B1	3	one correct path second correct path and no other
	Total		**9**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	$10 + 13 - 1 + 17$ $= 39$	M1 A1	2	3 values added and –1 (condone one slip)
(b)(i)	*DE* 12 *FG* 7	B1 B1	2	on Figure 2
(ii)	**arc** **forward** **backward** *SA* 3 1 *AB* 1 1 *BT* 0 1 *SC* 0 2 *CA* 0 1 *AD* 0 1 *CD* 1 1 *DE* 1 2 *BE* 1 3 *ET* 2 3 *SF* 1 1 *FC* 1 2 *FD* 1 0 *FG* 0 1 *DG* 2 1 *EG* 1 1 *GT* 2 3	M1 A1	 2	at least 6 pairs correct on Figure 3 (must have arrows) all correct
(iii)	**Table** **Path** **Extra Flow** *SABET* 1 *SFDGT* 1 *SACDGT* 1	M1 A1		1 correct path and extra flow all correct *DEG triangle may have different flows with implications to triangle GET.*
	Network  	M1 A1	 4	1 path correctly augmented forward and backward **bu**t must have earned M1 in part (b)(ii) network correct
(c)(i)	Max flow = 37	B1	1	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(c) cont.				
(ii)	Max flow 	B2	2	correct flow of 37 condone 2 slips or omissions in flow of 37 **or** "correct" feasible flow of 36 for SC1
(d)	Cut through *AB*, *AD*, *CD*, *FD* and *FG*	B1	1	$\{ S, A, C, F \}$ $\{ B, D, E, G, T \}$
	Total		**14**	
	TOTAL		**75**	